Entry Trajectory Reconstruction Using Phoenix Radio Link:

Deducing Martian Wind Velocities

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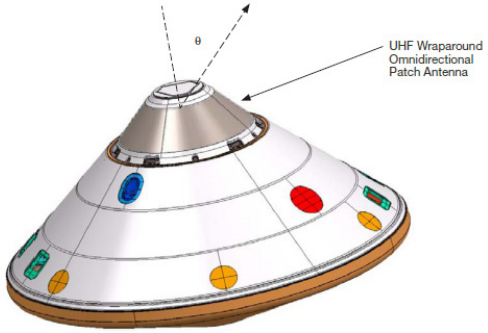
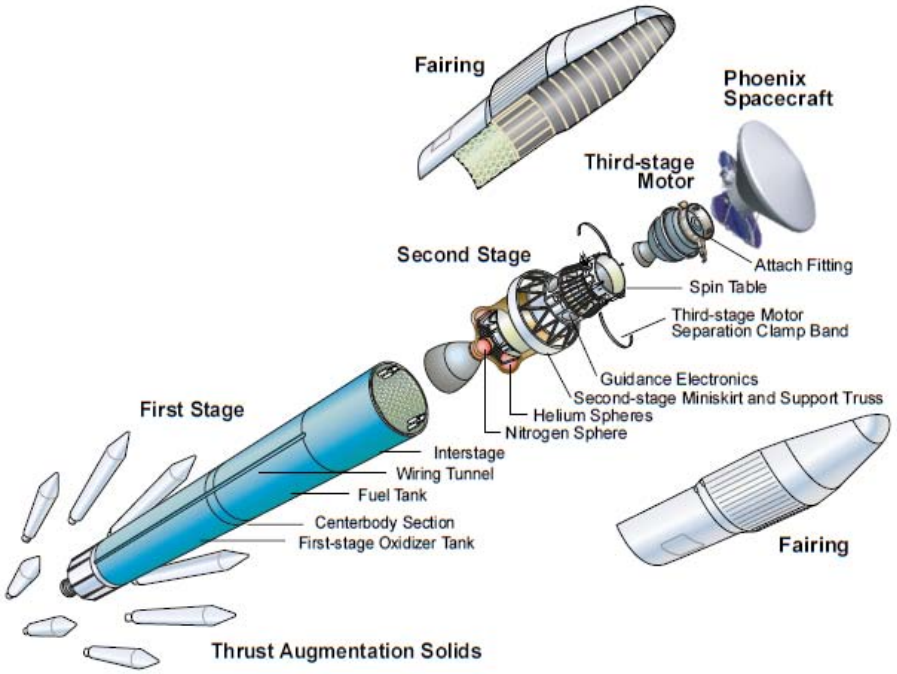
Overview

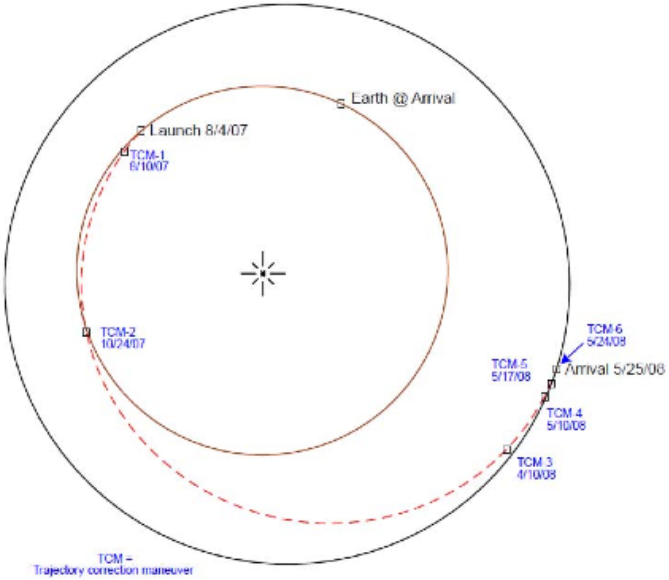
- The Phoenix Mars Lander entered Martian atmosphere on 25 May 2008
- All ensuing communications during EDL path were via an UHF uplink to a Mars orbiting spacecraft
- Odyssey orbiter relayed the Phoenix data to the DSN at Goldstone
- Direct UHF was received from the Green Bank Telescope
- The objective of this activity was to monitor the state of the lander during critical stages of the EDL
- The data can now be explored for utility to reconstruct the entry trajectory provided that the received UHF signal is not too noisy
- The recorded signal profile from Phoenix EDL can be processed to quantify the accuracy of the reconstructed trajectory and the atmospheric profiles (density, pressure, and temperature) determined along this trajectory



Phoenix Overview

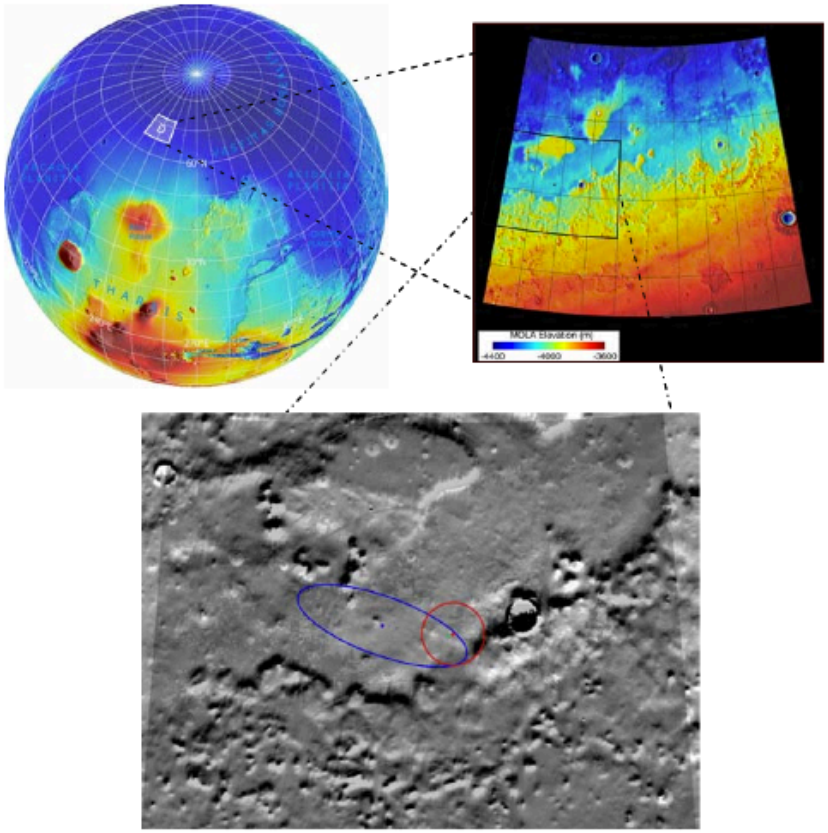
- The Phoenix mission was the first mission in NASA's Scout Program.
- Phoenix launched on a Delta II 7925 rocket from Cape Canaveral on 4 August 2007
- After a 10-month journey from Earth to Mars, Phoenix performed the first soft landing on Mars since the two Viking probes landed on Mars in 1976.

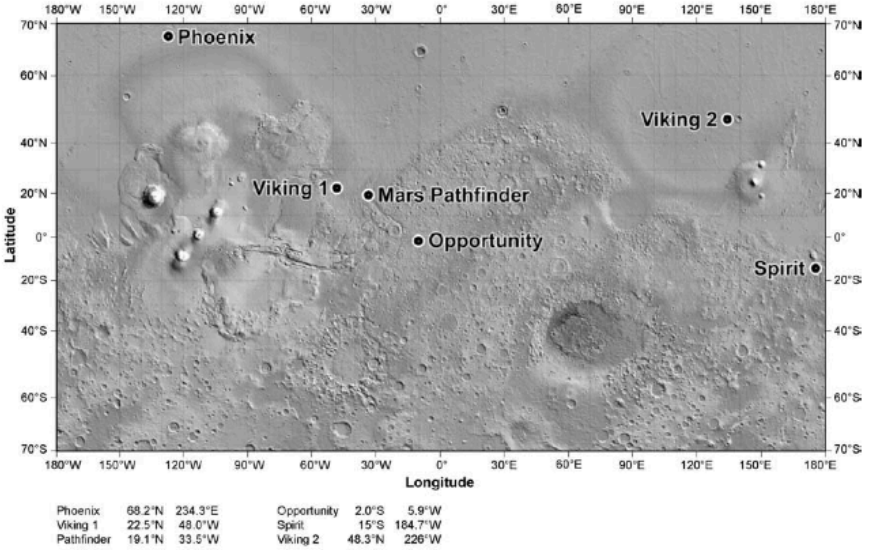




Landing Site

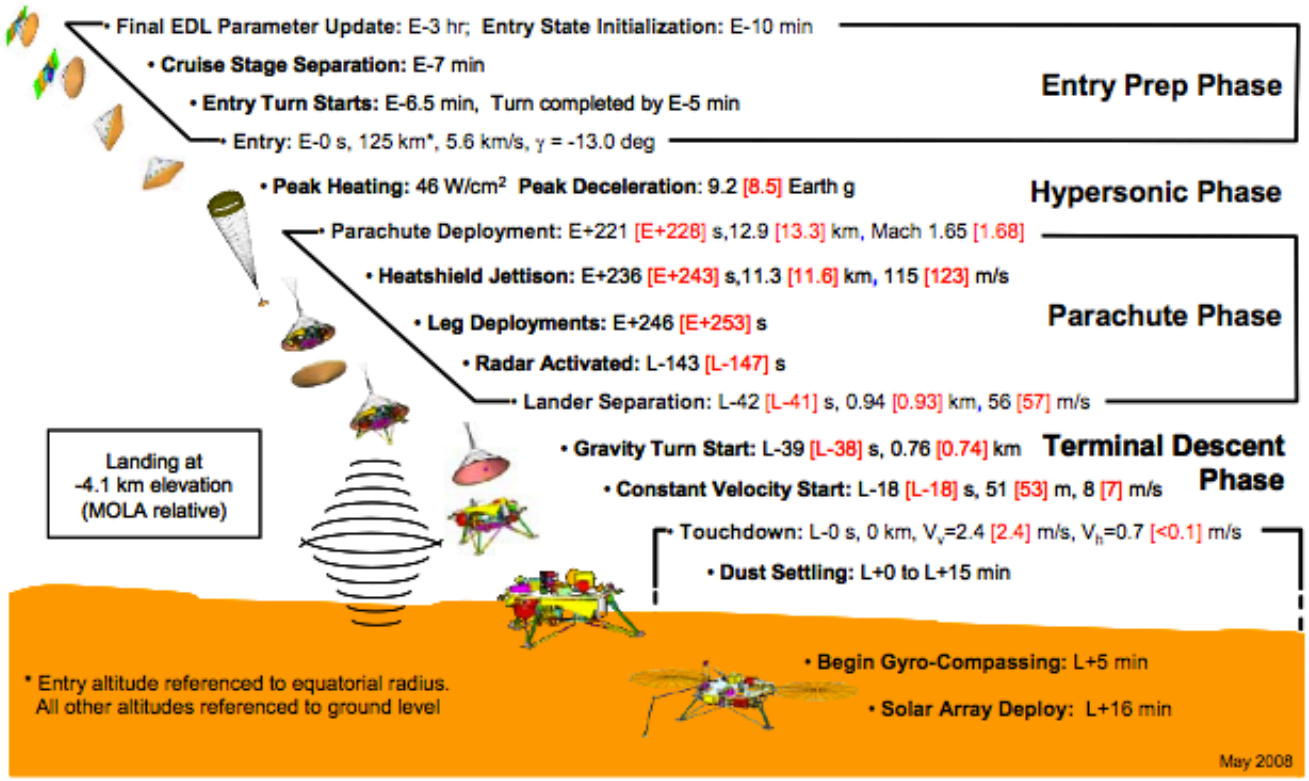
Phoenix successfully landed on the northern plains of Mars on 25 May 2008 (Vastitas Borealis region at 68.219 deg North Latitude and 234.248 deg East Longitude).





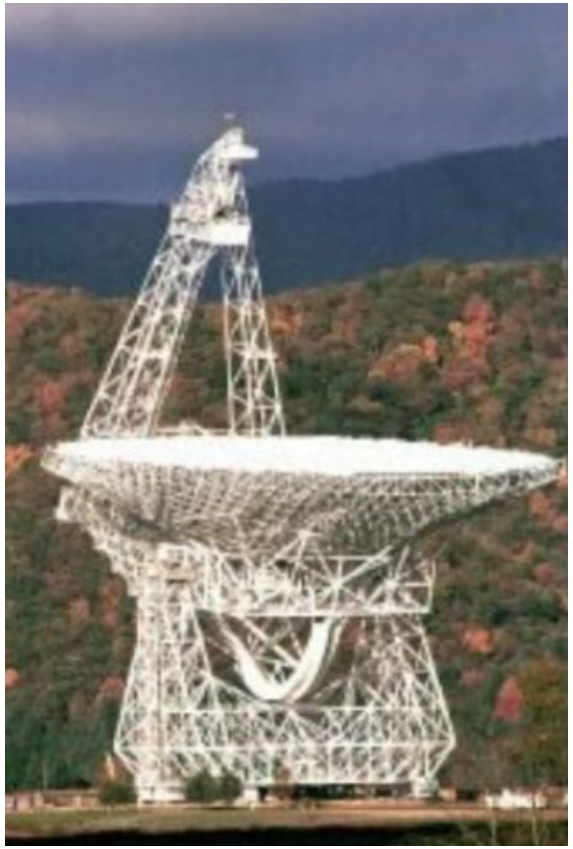
The Entry, Descent, and Landing (EDL)

- EDL phase had many critical events occurring over a short period of time, including cruise stage separation, entry into the Martian atmosphere, parachute deployment, lander separation, and terminal descent
- X-band telecom subsystem jettisoned with the cruise stage upon separation, with all subsequent EDL (and surface) communications through the UHF subsystem

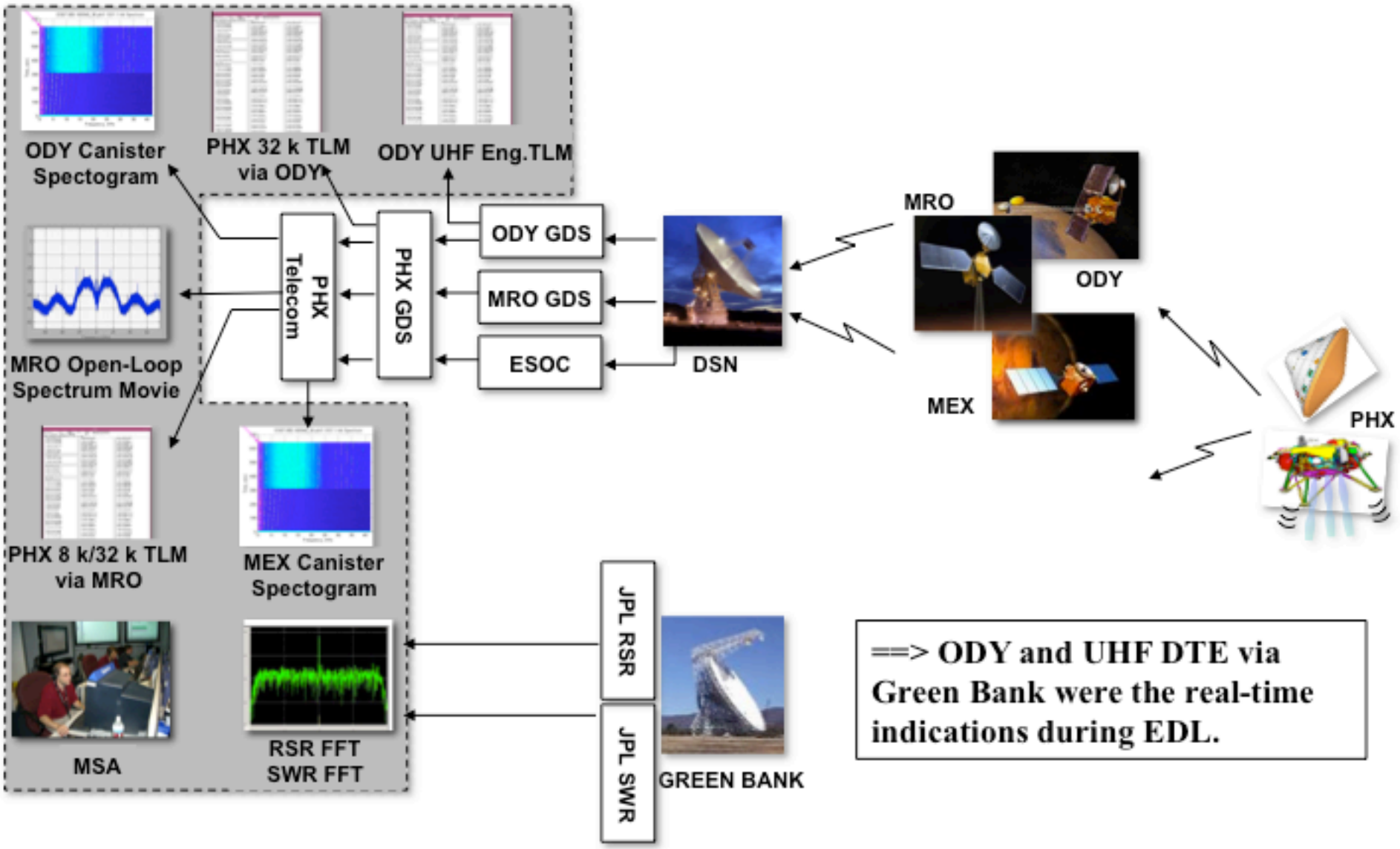


EDL Communications

- NASA levied a requirement on to provide communications coverage during all critical events sufficient to diagnose faults and/or failures, should they occur
- EDL architecture relied on establishing primary data links to relay spacecraft orbiting Mars
  - UHF relay link selected over direct-to-Earth X-band
- Radio Science & Phoenix project decided to eavesdrop from Earth on the UHF relay link from lander to orbiters
  - Green Bank Telescope (GBT) only capable facility c
  - Largest steerable radio telescope (100 m diameter)
  - Entire EDL was observable
  - Radio Science Receiver borrowed from DSN
- Recorded “open-loop” data proved to be rich with information on critical events, trajectory & other dynamics
- RSR used a-priori prediction file of the Doppler profile
- Residual frequency, the difference between the expected and actual Doppler profiles, sweeps a smaller frequency range and allows for easier determination of signal presence

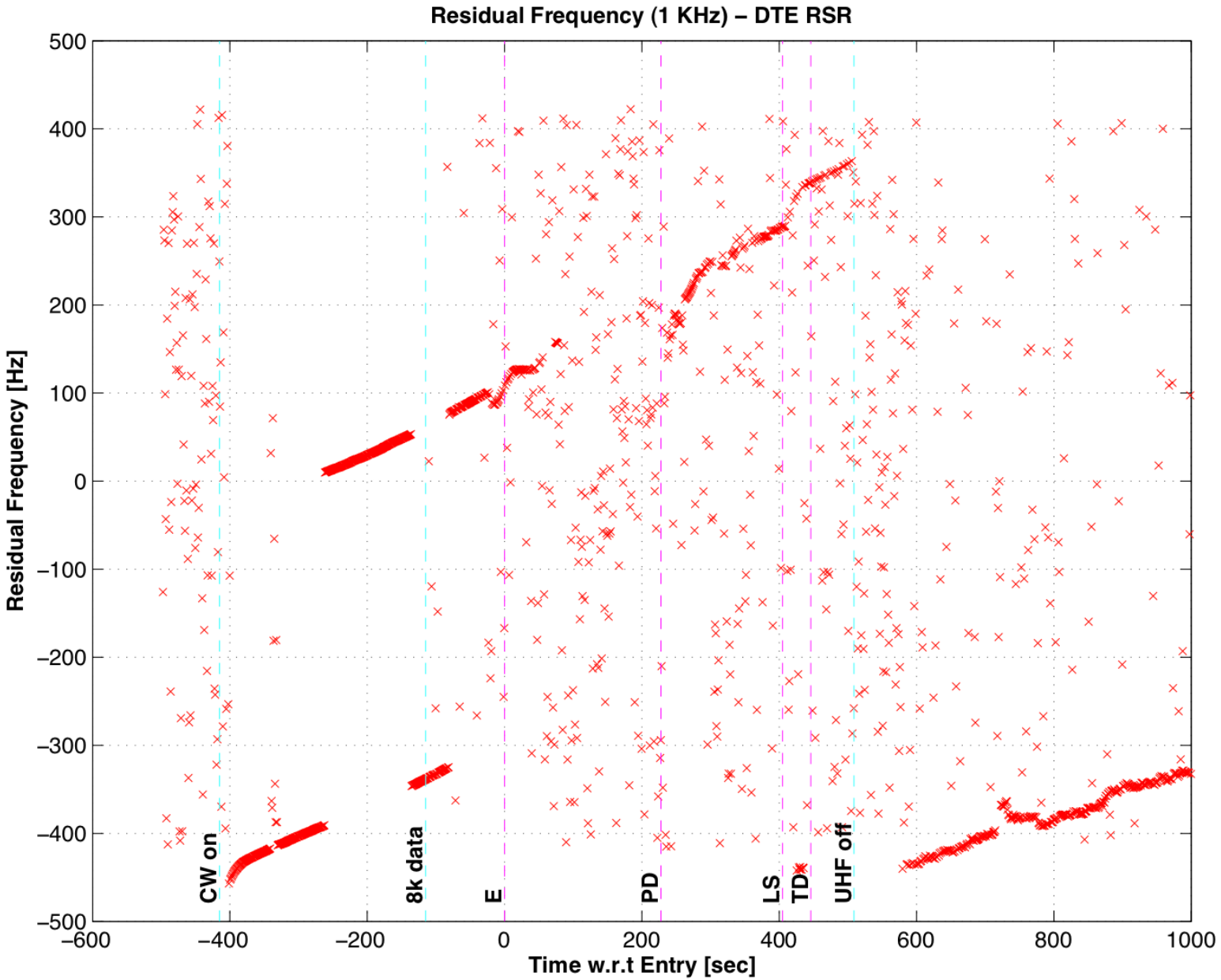


Top-Level EDL Communications Data Flow

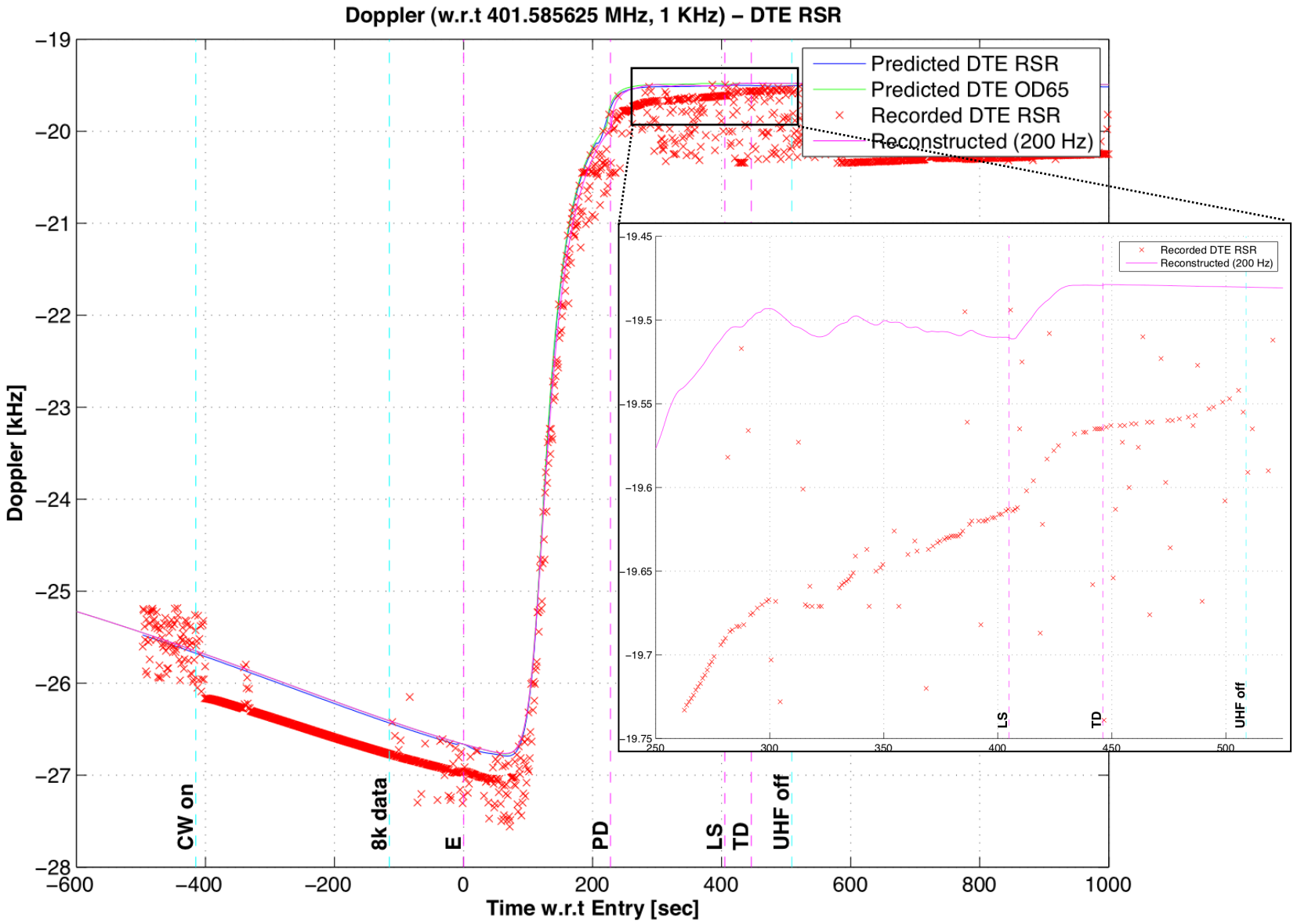


==> ODY and UHF DTE via Green Bank were the real-time indications during EDL.

DTE RSR Residual Frequency

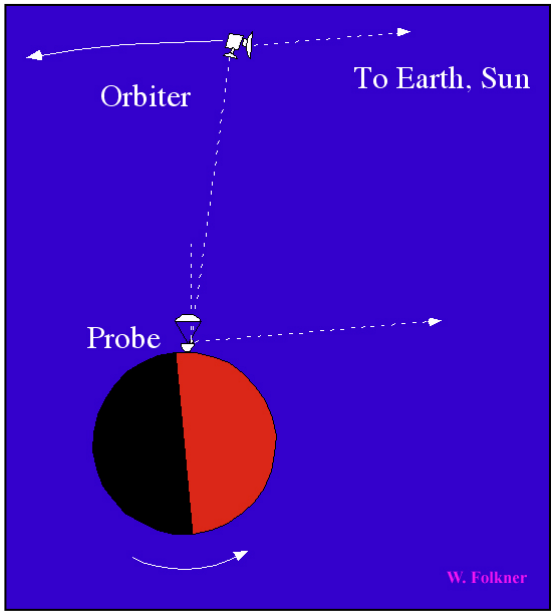


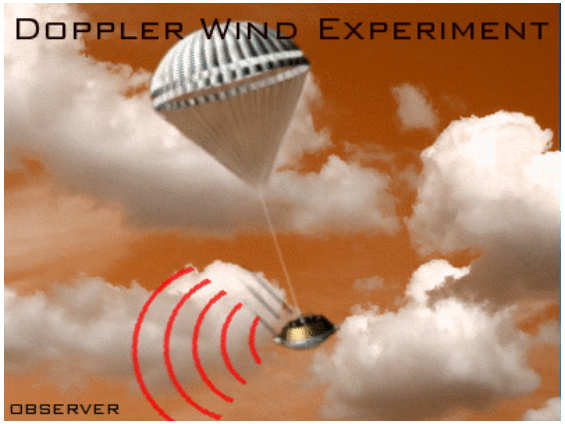
DTE RSR Doppler



Detectable Wind

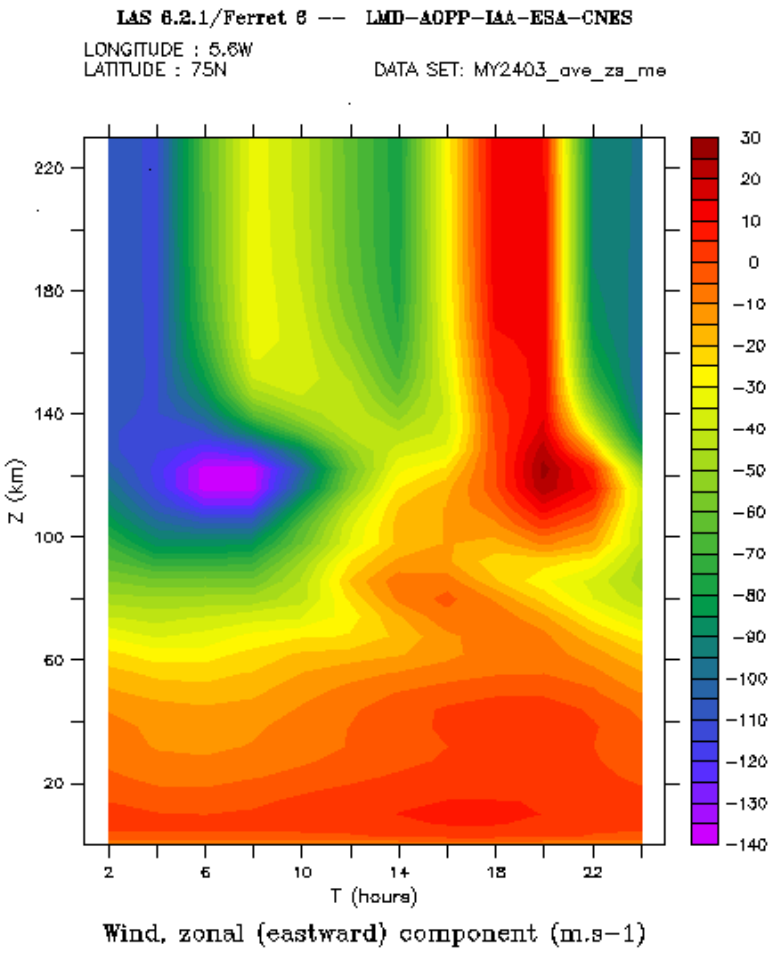
- After parachute deploy, period of fall in lower atmosphere
- Accurate Doppler reconstruction and trajectory dynamics removed
- Near linear drift of spacecraft oscillator, fitted out
- Remaining signal contains fluctuations consistent with effect of wind
- Doppler signals between 20 and 100 Hz detectable
- Imply line of sight velocity of order 30 m/s
- Very consistent with models in LMD climate database

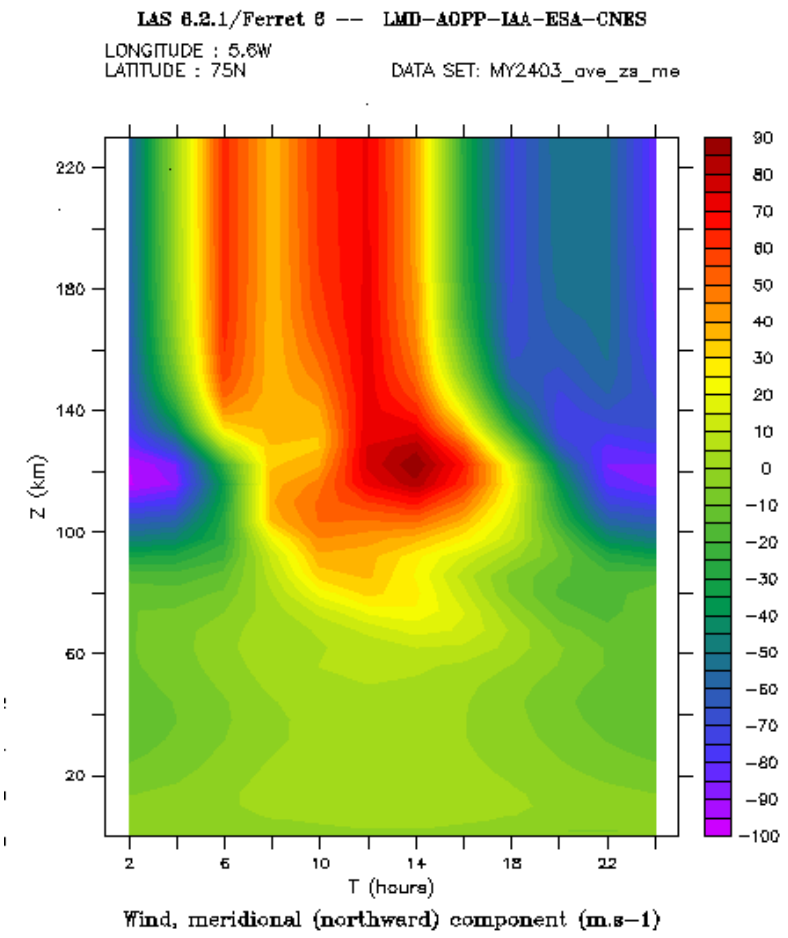




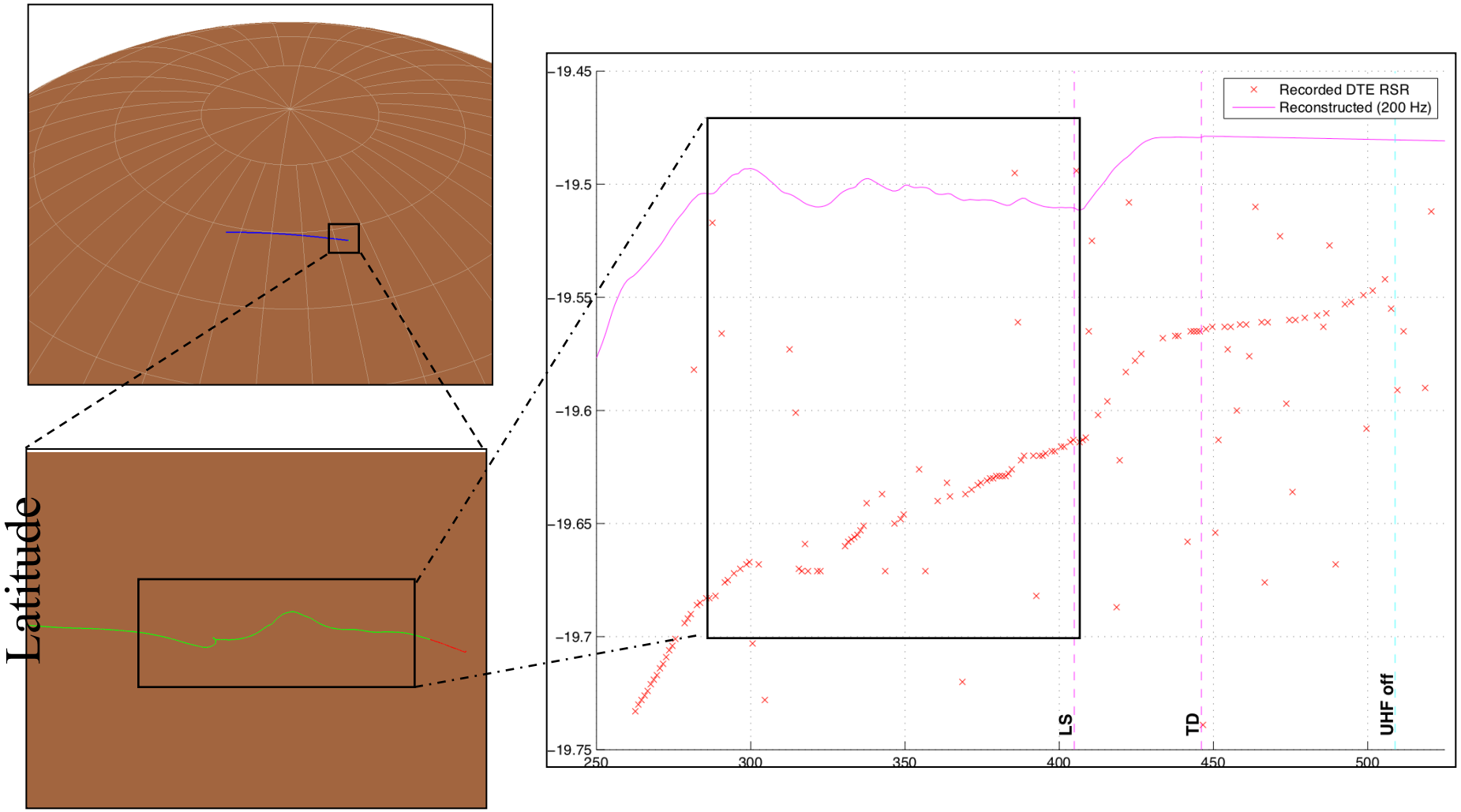
Graphics Asmar, Huygens DWE

Winds from LMD Climate Data Base





Low Altitude Winds



From R. Kornfled

Potential for Improved Reconstruction

- Phoenix descent profile Doppler observation can potentially contribute to wind speed measurements, data that are lacking from current input to GCM
- Preliminary processing of Direct-to-Earth UHF data captured at GBT provide line-of-sight direction (one vector)
- Processing relay Doppler to MRO, ODY, and MEX can lead to useful 3-D reconstruction
- If validated, can prove to be useful science by-product from EDL "tracking"
- Galileo and Huygens Doppler Wind Experiments worked but were designed with better oscillators